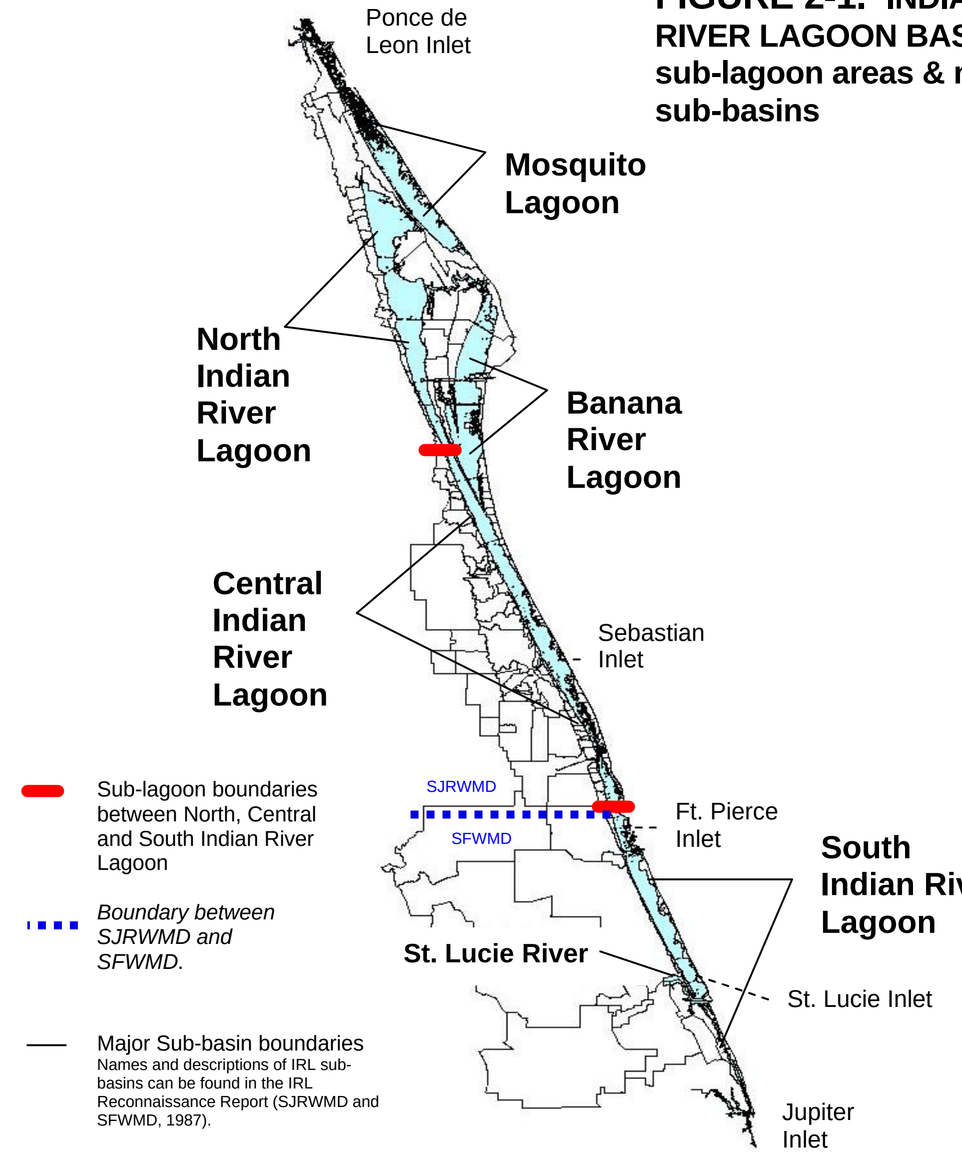
CHAPTER 2. A LAGOON-WIDE OVERVIEW

Introduction

This chapter is devoted to an overview of the IRL system: a summary report on its status with respect to its seagrass, water quality, and coastal wetland resources, and a summary discussion about those strategies and projects which have application throughout the IRL Basin in both the SJRWMD and SFWMD (Figure 2-1).

The first major section in this chapter, *Seagrass and Water Quality*, opens with a brief report on the Lagoon-wide status of seagrass and water quality. This report is based on the general findings of the monitoring and diagnostic projects in the *Seagrass*

FIGURE 2-1. INDIAN RIVER LAGOON BASIN sub-lagoon areas & major sub-basins



and Water Quality program and constitutes an interpretation of the condition and trends of seagrass and water quality in the IRL system during the 1990s. Similar status reports specific to the sub-lagoon regions – Mosquito Lagoon, Banana River Lagoon, North, Central and South IRL, and St. Lucie River – are found in Chapters 3 - 6.

Following the status report are the general descriptions of the projects and basic management approaches that have Lagoon-wide application (e.g., monitoring networks, diagnostic investigations, general approach to non-point and point source management, reconnection of impounded wetlands, etc.). The project descriptions include their progress and what is planned over the next 5 years. The project descriptions are organized by program: *Seagrass and Water Quality*, *Coastal Wetlands*, and *Public Involvement and Education*. These programs were initiated in 1988/89, at the inception of the IRL SWIM Program. For information on project progress prior to 1994, please refer to the 1994 IRL SWIM Plan. Project progress since 1994 is discussed in this plan update within their respective programs.

An Overview of the Programs – Seagrass and Water Quality, Coastal Wetlands, Public Involvement and Education

The *Seagrass and Water Quality* program largely consists of projects that have a diagnostic or feasibility assessment function -- assessing the health of the Lagoon's seagrass resource, defining the impacts to this resource, setting restoration targets or performance measures, and recommending and evaluating strategies to achieve those targets. Since 1994, additional efforts have been placed on implementing management strategies and evaluating pollutant load reduction efficiencies and costs for some representative projects (e.g., stormwater treatment basins and sediment traps).

The *Coastal Wetlands* program is engaged in the rehabilitation of impacted coastal wetlands, particularly impounded wetlands (a.k.a. mosquito control impoundments). In contrast to the *Seagrass and Water Quality* program, the *Coastal Wetlands* program benefited from over a decade's worth of diagnostic and feasibility research[1] in Lagoon wetland management prior to the passage of the 1987 SWIM Act. Such research led to the development of methods for reconnecting and managing impounded wetlands that allow a large degree of ecological recovery and sustainability but still provide for mosquito control. Consequently, the Districts immediately launched a Lagoon-wide campaign at the inception of the SWIM program to reconnect and rehabilitate tens of thousands of acres of impounded wetlands. Progress toward that goal and what is planned over the coming years to complete that goal -- and even go beyond -- are the main subjects of the *Coastal Wetlands* section.

The *Public Awareness* program, renamed *Public Involvement and Education* (PIE), has been fully managed by the IRL National Estuary Program (IRLNEP) since 1994. Through the IRLNEP's exceptional efforts, public awareness, and support have grown steadily. Maintaining a high level of awareness and eliciting support for restoration projects is a constant challenge. When one considers the fact that nearly 400 people move into the IRL basin every week, the on-going process of public awareness should

[1] Much of that research was jointly conducted by Florida Medical Entomology Laboratory (Vero Beach), Harbor Branch Oceanographic Institution, and the local Mosquito Control Districts.

be a mainstay of any large restoration program. For details on the PIE program's strategies and projects, please refer to pages 238 – 251 of the IRLNEP's Comprehensive Conservation and Management Plan. This SWIM Plan update briefly covers progress and accomplishments, and what milestones are established for the future.

Seagrass and Water Quality

Lagoon-wide Status of Seagrass and Water Quality

Seagrass Resource Assessment. The Districts' assessment of the IRL seagrass resource is based on three measurement indices:

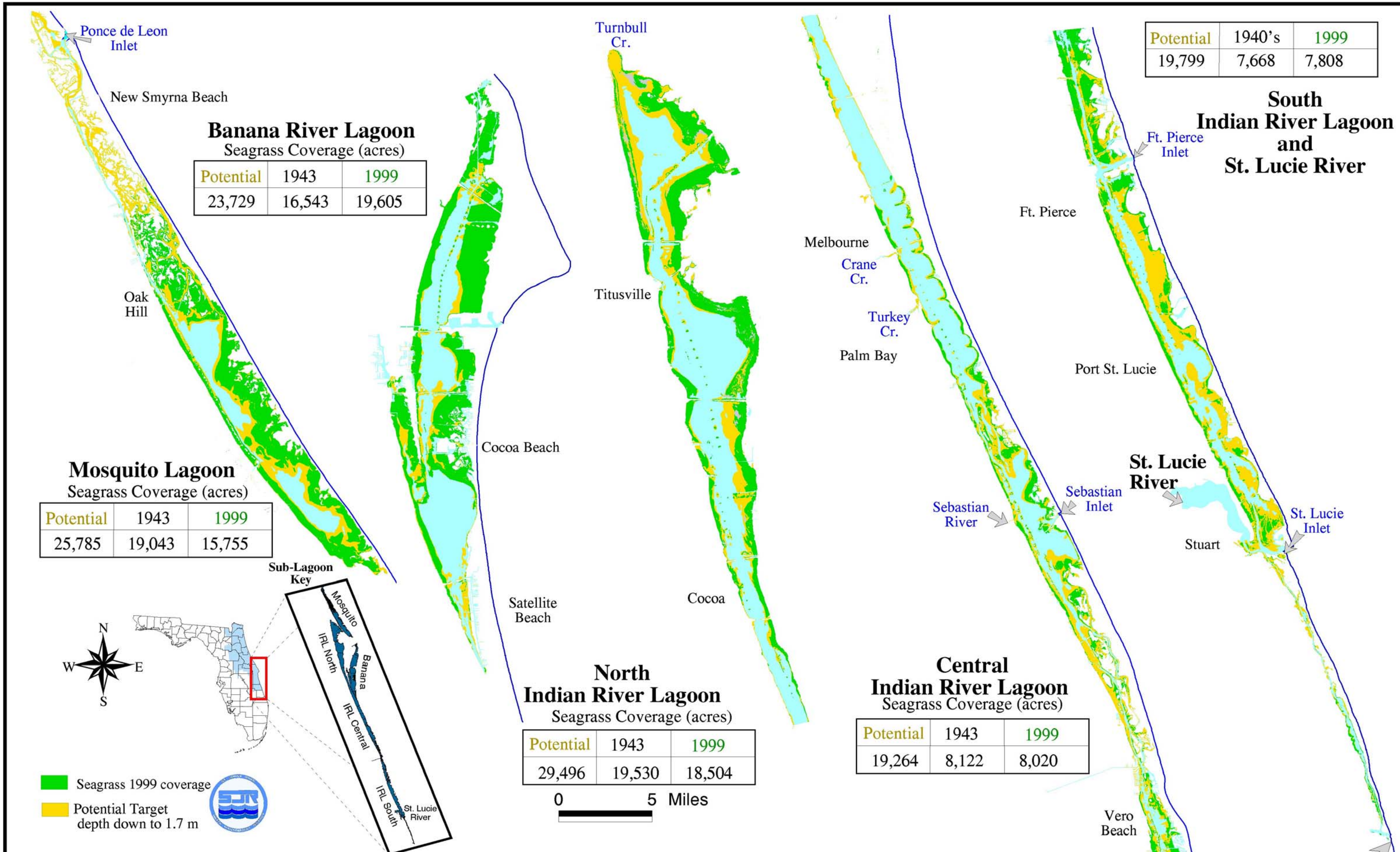
- Acres of seagrass coverage gain or loss
- Maximum depth of the edge of seagrass beds, and
- Percent of total surface sunlight that reaches the targeted depth of 1.7 m

Seagrass coverage is evaluated against multiple targets. Both Districts considered the potential coverage, based on a target depth of 1.7 m, and 1940 - 1943 mapped coverages, which are the earliest documented coverage years known for the IRL. Based on "healthy" areas of the Lagoon, the Districts set a target depth of 1.7 m (5 ft 7 in)[2] to which seagrass can grow if given optimal conditions (Morris et al., 2002). Therefore, gauging the maximum depth of the edge of seagrass beds is as important a measure of health as is areal coverage. Finally, the extent to which sunlight reaches the target depth of 1.7 m is a measure of the water clarity condition: the clearer the water, the more light reaches the bottom, and the greater potential there is for seagrass growth and expansion.

Seagrass coverage distributions vary widely throughout the IRL system (Figure 2-2; IRL seagrass coverages in the 5 sub-Lagoons and the St. Lucie River). Major findings about seagrass coverage distribution in the IRL are summarized below (refer to Figure 2-2 for additional detail).

- Lagoon areas containing the largest seagrass coverages are around N. Merritt Island in the federally protected bottomlands of NASA/Kennedy Space Center (North IRL and northern Banana River) and the Canaveral National Seashore (southern Mosquito Lagoon). These areas experienced little change between 1943 and 1999.
- The largest area with the least seagrass coverage, and with the greatest loss since 1943 (70% loss), extends from Cocoa to just south of Turkey Creek
- Within the SJRWMD portion of the IRL (Mosquito Lagoon, Banana River, North and Central IRL), the current (1999) 61,884 acres of seagrass is 63% of the potential 98,274 acres of coverage (based on 1.7 m depth). The 1943 seagrass coverage was 63,238 acres; 64% of the potential acreage.
- Within the SFWMD portion (South IRL), the current (1999) seagrass cover is 7,808 acres or 39% of the potential 19,799 acres. The early 1940s seagrass coverage was nearly the same – 7,668 acres or 39% of the potential acreage.
- For the entire IRL, the potential coverage area for seagrass is 118,000 acres; but only 59% of that is currently covered in seagrass (69,692 acres in 1999).

[2] Depth is referenced to NAVD88 by SJRWMD and to NGVD29 by SFWMD.



The St. Johns River Water Management District prepares and uses this information for its own purposes and this information may not be suitable for other purposes. This information is provided "as is". Further documentation of this data can be obtained by contacting: St. Johns River Water Management District, Geographic Information Systems, Program Management, P.O. Box 1429, Palatka, Florida 32178-1429. (904) 329-4176.

Figure 2-2 Seagrass Coverages in the Indian River Lagoon System

Maps show potential* and current (1999) seagrass coverage. The estimated coverage in 1943 is provided in the tables for comparison

*Potential area coverage is based on 1.7 m depth referenced to the NAVD88 vertical datum, except in South IRL where depths were referenced to NGVD29

- In general, "healthy" seagrass areas are adjacent to relatively undeveloped watersheds or in proximity to inlets, whereas areas of extensive losses are adjacent to highly developed watersheds and shorelines.

The Relationship of Light to Seagrass. It is believed that light limitation is the primary reason for restricting seagrass from growing into deeper water (Morris and Tomasko, 1993; Woodward-Clyde, 1994a). Preliminary analysis of IRL data[3] indicates that nearly 50% of the variability in the depth of seagrass coverage can be explained by the amount of light that can penetrate Lagoon waters[4]. This means that if we can sufficiently increase light penetration, then seagrass should measurably expand.

What is regarded as a *sufficient* amount of light? One way to determine whether there is enough light is to measure the percent of surface light that reaches the target depth of 1.7 m and compare that to some light requirement level. The preliminary minimum light requirement for IRL seagrass is about 25% of the surface light based on the annual median of the percent surface light at the deep edges of seagrass beds. This finding is in good agreement with the scientific literature, which suggests that seagrass light requirements may range from 15% to 37% of surface light (Kenworthy, 1993; Morris and Tomasko, 1993; Kenworthy and Fonseca, 1996).

It appears that throughout the IRL, the percent of surface light reaching 1.7 m falls short of the minimum "25% requirement" (SJRWMD and SFWMD monitoring data; Figure 2-3a and b). The North IRL (near Titusville) and the Jupiter Inlet segment come closest to meeting this incipient standard, receiving nearly 25% or more of surface light. The areas that exhibit good to fair light penetration, 15% of surface light or more, typically have the best seagrass coverage: southern Mosquito Lagoon, northern Banana River, North IRL (near Titusville), and near Sebastian and Jupiter inlets.

Unexpectedly, Mosquito Lagoon exhibits poor light penetration to 1.7 m (Figure 2-3b) although seagrass coverage in its central and southern segments has been very stable since 1943. This may be explained by Mosquito Lagoon's shallowness; less than 1.3 m average; whereas the other Lagoons average 2 to 2.4 m in depth. This shallow depth may lend itself to more wind-induced turbid conditions, limiting light; however, an adequate amount of light is still available at its shallow bottom to maintain expansive beds of seagrass. (There is more about Mosquito Lagoon in the water quality discussions below and in Chapter 3.)

The fact that the preliminary light requirement is not met throughout the IRL may explain why the deep edge of seagrass is generally less than the target depth of 1.7 m (Figure 2-3c; the seagrass depth index = measured depth of seagrass edge in meters as a percent of the 1.7 m target depth). A notable exception is the Jupiter Inlet area where the deep edge of seagrass exceeds 1.7 m (Figure 2-3c). But elsewhere in the IRL, the deep edge of seagrass reaches 0.9 -1.5 m, or 58% - 87% of its potential depth of 1.7 m. The better seagrass coverage segments – northern Banana River Lagoon, North IRL, and around inlets – achieve over 80% of the 1.7 m potential seagrass coverage depth.

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[3] Data collected via Districts' water quality and seagrass monitoring networks, 1990 – 1999.

[4] Other factors that may limit the depth to which seagrass may grow are instability of sediments induced by hydrodynamics or other forces, sediment quality (e.g., hypoxia, grain size), competition by other plants like attached macroalgae, and shading by drift macroalgae. Some of these factors that can be managed may need to be addressed to further seagrass restoration.

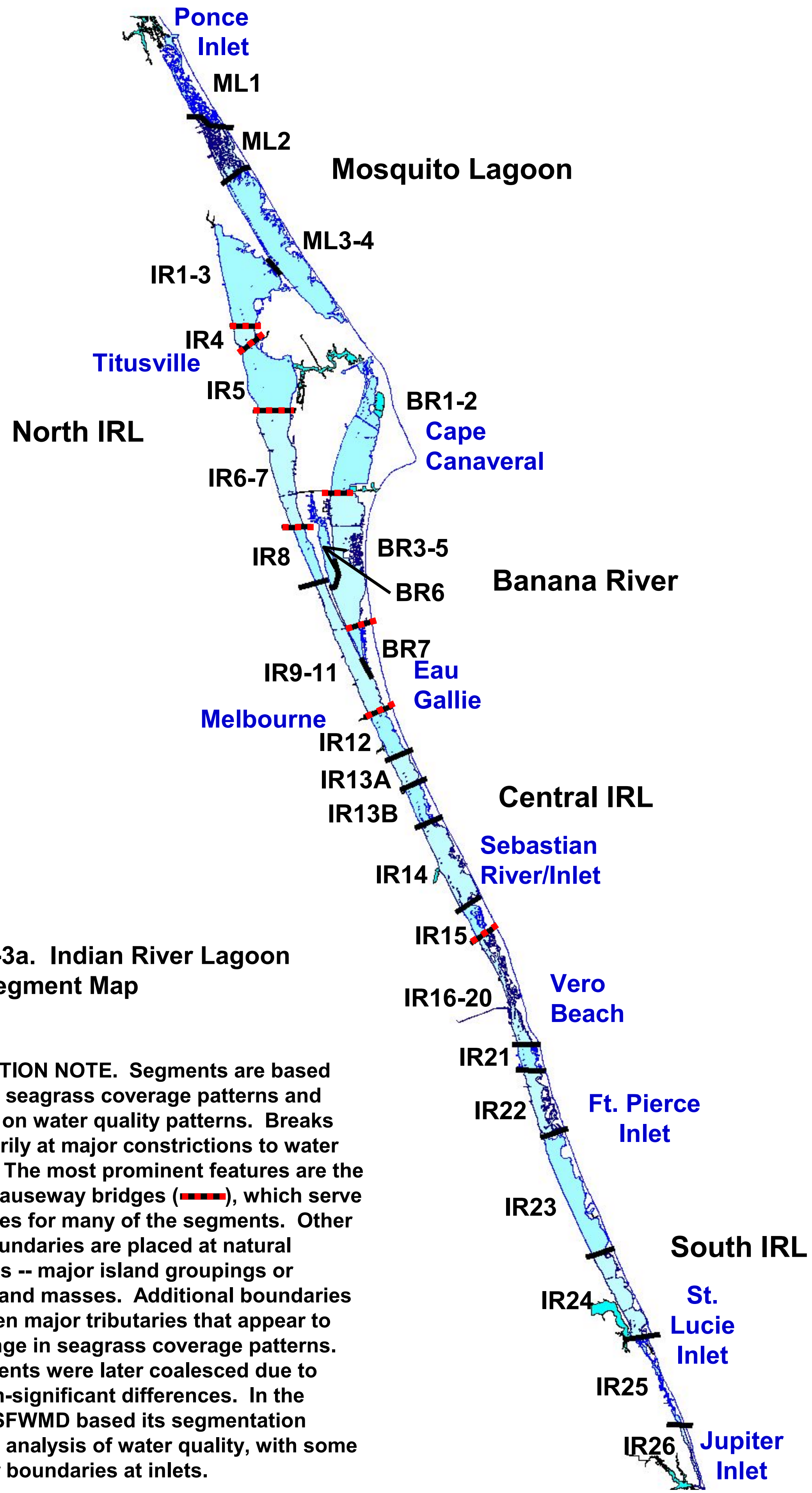


Figure 2-3a. Indian River Lagoon System Segment Map

SEGMENTATION NOTE. Segments are based primarily on seagrass coverage patterns and secondarily on water quality patterns. Breaks occur primarily at major constrictions to water circulation. The most prominent features are the numerous causeway bridges (▬▬), which serve as boundaries for many of the segments. Other segment boundaries are placed at natural constrictions -- major island groupings or peninsular land masses. Additional boundaries were between major tributaries that appear to induce change in seagrass coverage patterns. Some segments were later coalesced due to small or non-significant differences. In the South IRL, SFWMD based its segmentation primarily on analysis of water quality, with some of the major boundaries at inlets.

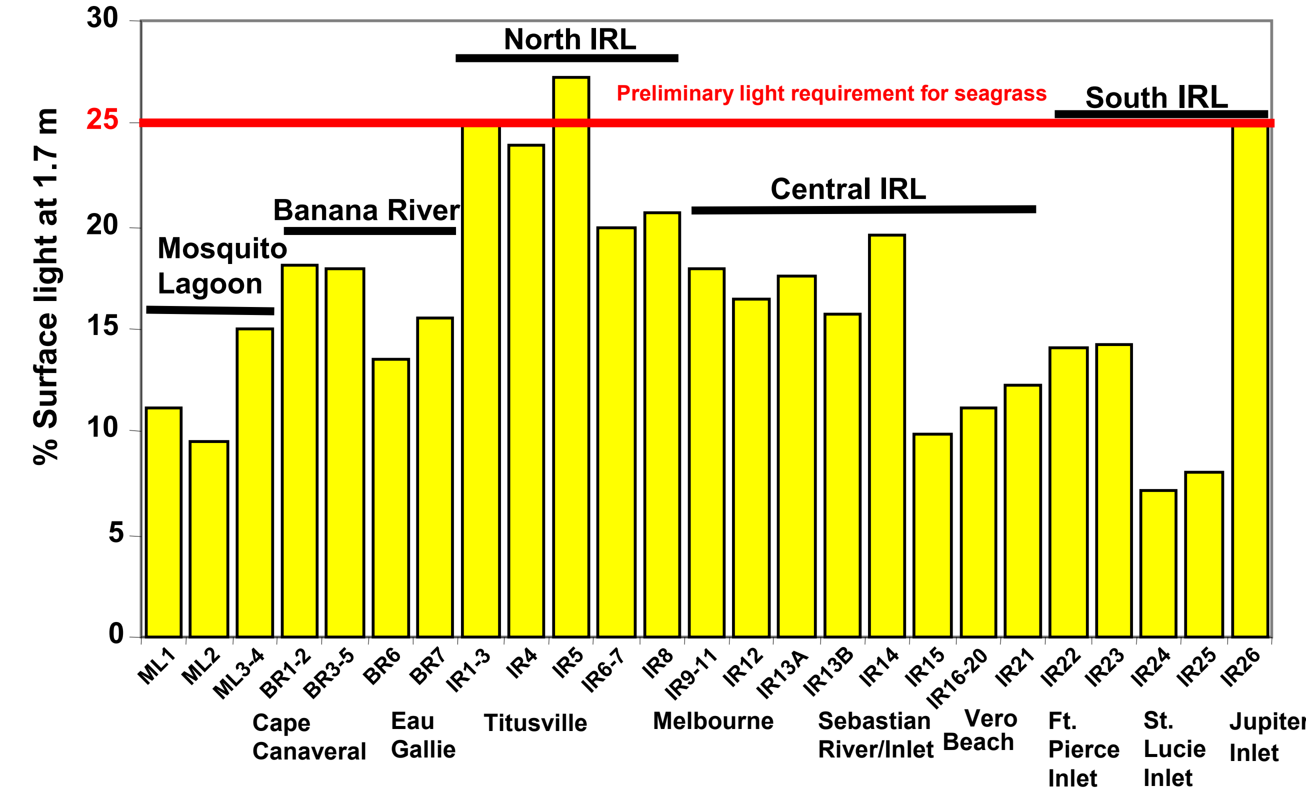


Figure 2-3b. Median percent surface light at the 1.7 m target depth for each segment, north to south (see map at left for location of segments). Based on monthly measurements from 1990 to 1999.

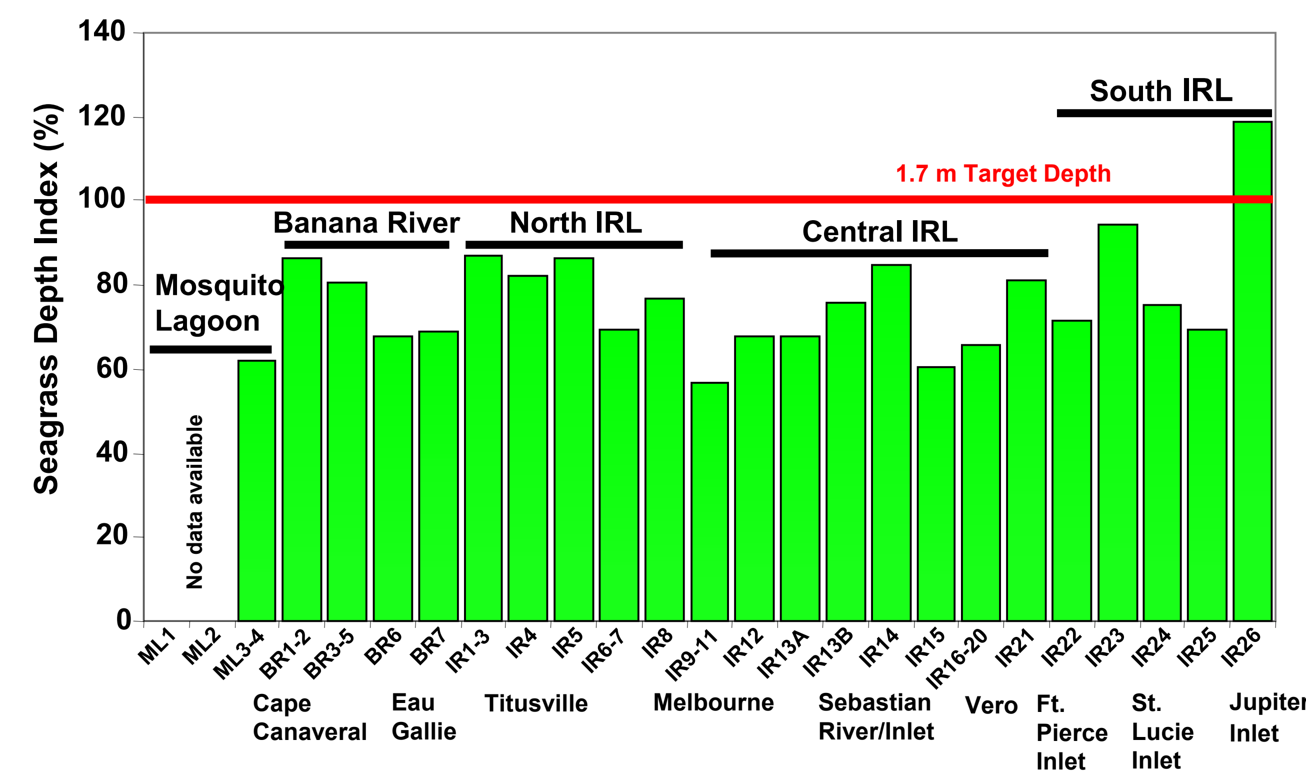


Figure 2-3c. Average Seagrass Depth Index -- depth of edge of bed as a percent of 1.7 m target depth*. Based on seagrass deep edges mapped in 1992, 1994, and 1996. (See map at left for location of segments.)

* The Seagrass Depth Index (SDI) is based on potential coverage to 1.7 m referenced to the NAVD88 vertical datum, except in South IRL where depths were referenced to NGVD29. The SDI would be slightly less if potential coverage were referenced to mean water level (MWL).

Poor vs. Good and Fair Seagrass Areas. IRL segments are identified as "poor" (considered as critical seagrass restoration areas), "good", or "fair" based on the three measurement indices: percent loss of seagrass since the 1940s, the percent of surface light reaching the 1.7 m target depth, and the depth of seagrass edge as a percent of the 1.7 m depth (a.k.a. seagrass depth index). The results are shown in Figure 2-4. For an explanation on how the indices are used to classify segment, refer to either Tables 3-1, 4-1, 5-1 or 6-2 in the following chapters.

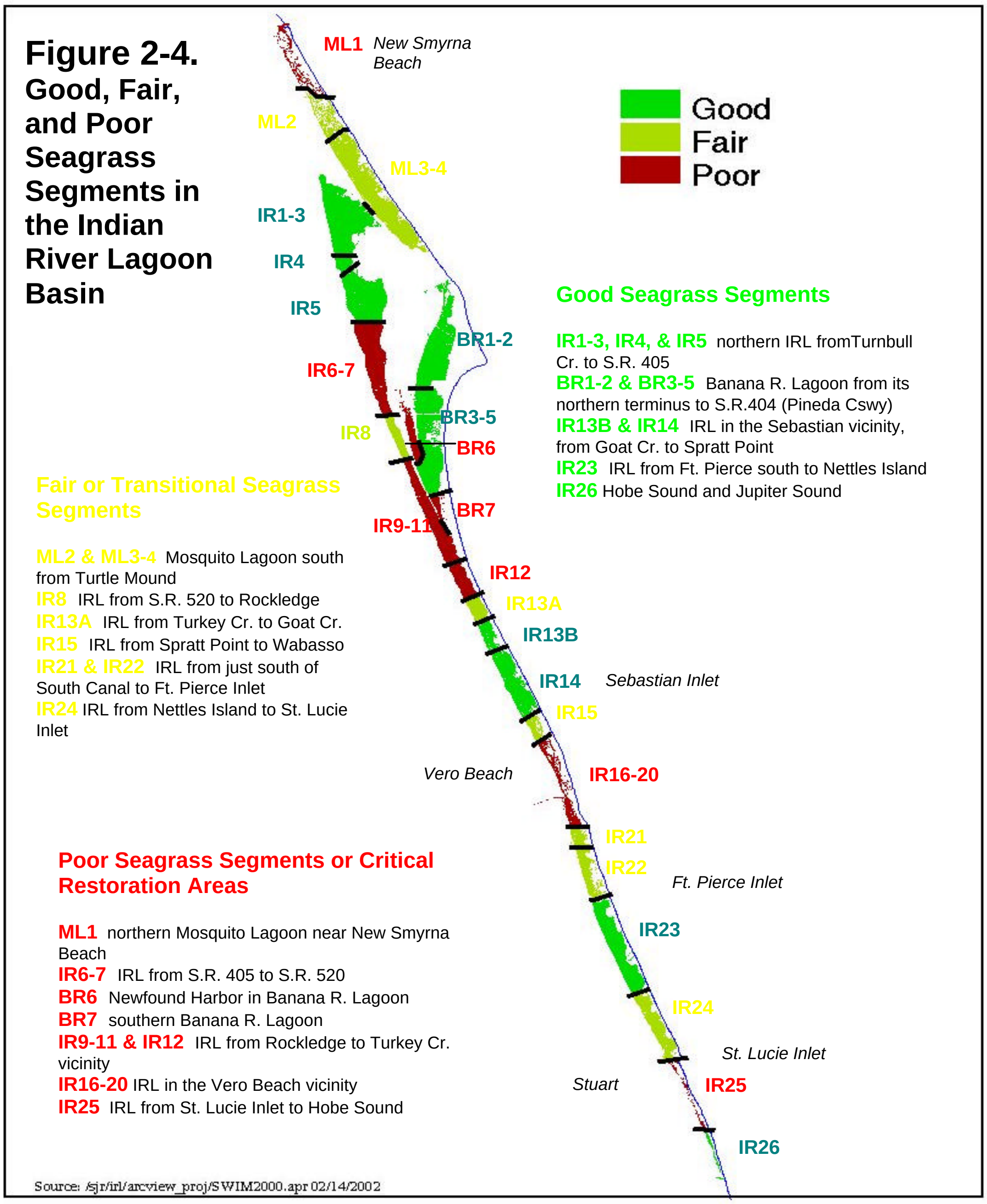


Figure 2-4. Good, Fair, and Poor Seagrass Segments in the Indian River Lagoon Basin

Water Quality Assessment. This assessment is focused on the water quality conditions germane to the seagrass resource with special emphasis on the major water quality factors that may limit light penetration to the Lagoon bottom. The major factors are:

- **Salinity**

An indication of the degree of mixing between marine and fresh waters; the optimum salinity for seagrass growth is above 20 parts per thousand (Reid, 1954; Voss & Voss, 1954; and Humm, 1956); ocean salinity averages 35 parts per thousand. Salinity does not affect light penetration but does affect seagrass species presence/absence and, potentially, overall seagrass coverage.

- **Color**

A relative measure of dissolved substances in the water column that can absorb light

- **Turbidity**

A measure of the degree to which light traveling through the water column is scattered by suspended material.

- **Total Suspended Solids**

Organic and inorganic particles suspended in the water column, which are probably responsible for most the light scatter and turbidity

- **Nitrogen and Phosphorus**

These macro-nutrients are indirect factors affecting light penetration; however, they are important because they 'fuel' phytoplankton and epiphyte growth (read chlorophyll *a* below)

- **Chlorophyll *a***

A component of phytoplankton that absorbs light; can effectively compete with seagrasses for available light if phytoplankton are abundant

This water quality assessment, based on the major factors above, is presented in two parts: (1) a general spatial overview of IRL water quality during 1990 - 1999, and (2) a preliminary identification and discussion of those water quality factors that predominantly affect light penetration in the critical restoration areas (as shown in Figure 2-4). Please refer to Chapters 3 - 7 for additional sub-lagoon detail about water quality, which includes a discussion on temporal trends during the past decade.

General Overview of IRL Water Quality (1990 – 1999). The following discussion is based on the results provided in Figures 2-5 and 2-6.

During the 1990s, throughout the length of the IRL system (tributaries excluded), the10-year average salinities were above 20 ppt and generally well within the optimum salinity range for seagrass growth. The highest average salinities, 29 – 33 ppt, were typically found in Mosquito Lagoon and South IRL, followed closely by North IRL (north of Titusville) and the areas near Sebastian Inlet and Ft. Pierce Inlet.

The lowest average salinities, hovering just above 20 ppt, were found in the southernmost reach of Banana River Lagoon (south of S.R. 404, Pineda Causeway) and in the Melbourne area of the Central IRL. Those areas are distant from oceanic influence, located 15 to 25 miles from Sebastian Inlet, and receive large volumes of urban drainage and tributary creek discharges (Horse, Eau Gallie, Crane, and Turkey Creeks). Salinities have dropped below 20 ppt for extended periods (months).

The 20 ppt level could be the critical minimum growth threshold for all the IRL seagrass species except *Ruppia maritima*, which can grow at lower salinities. If the average annual or seasonal salinity is below 20 ppt, especially during the growing season, the

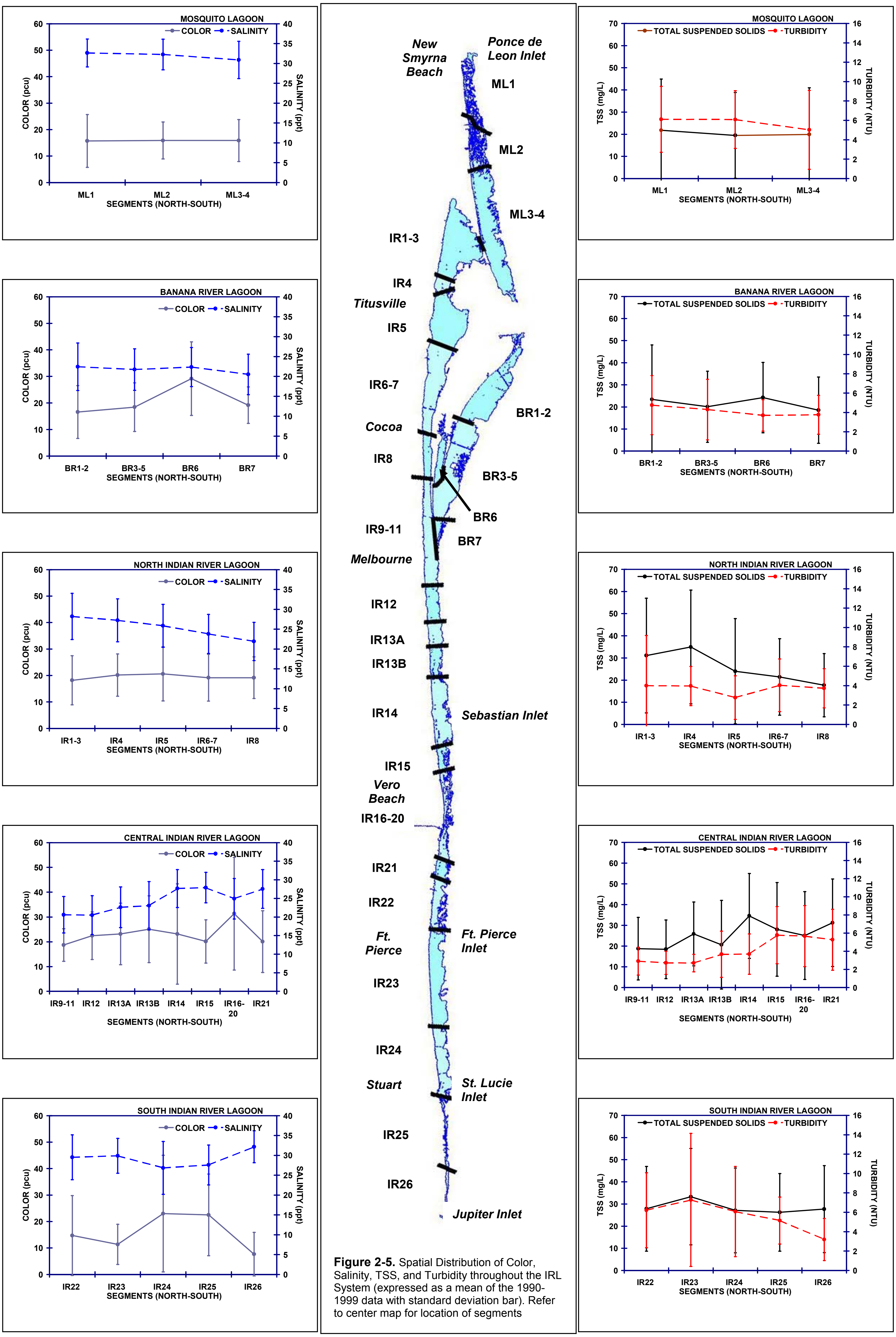
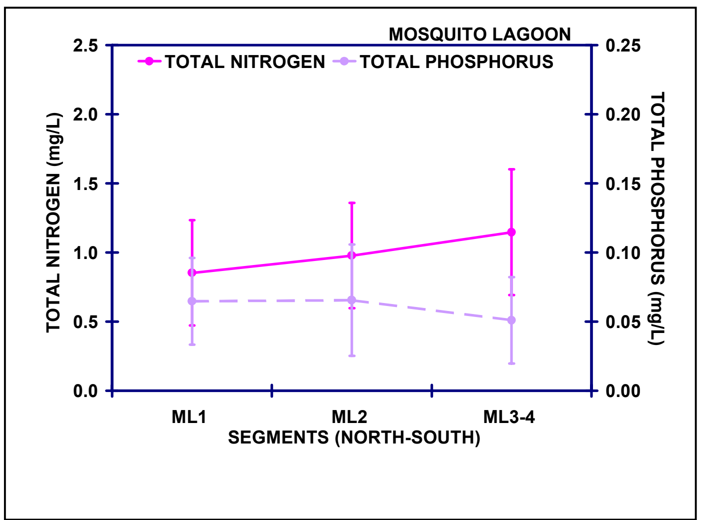
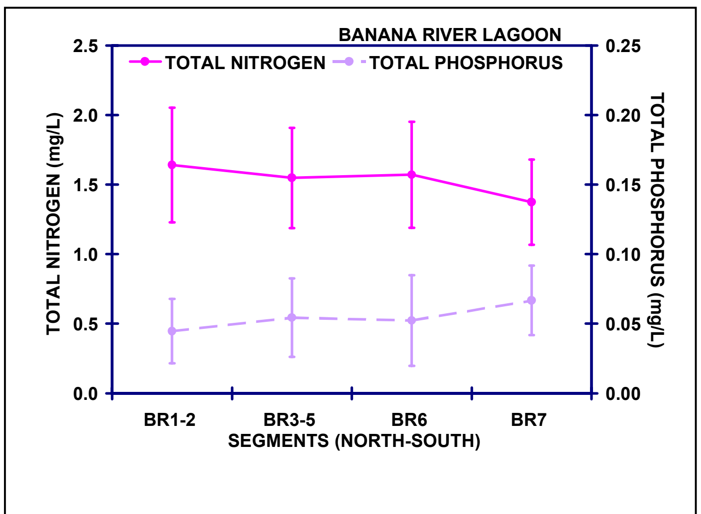
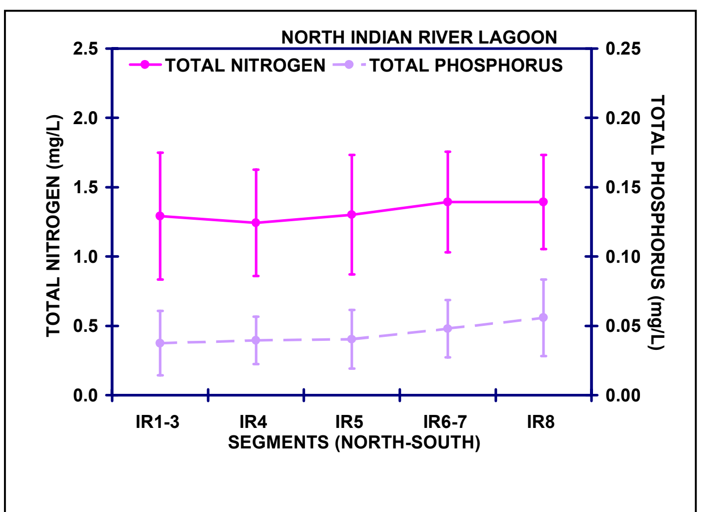
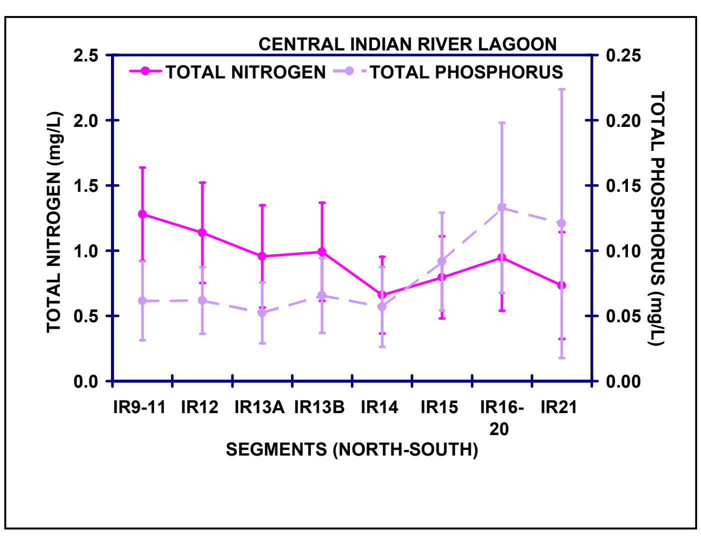


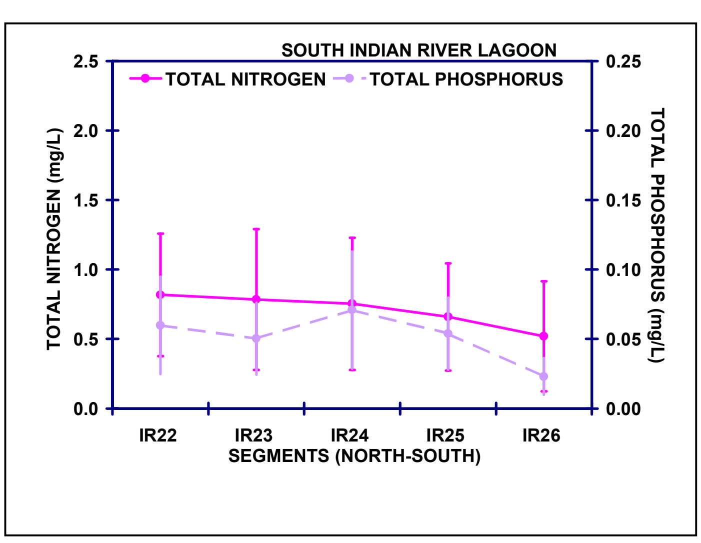
Figure 2-5. Spatial Distribution of Color, Salinity, TSS, and Turbidity throughout the IRL System (expressed as a mean of the 1990-1999 data with standard deviation bar). Refer to center map for location of segments











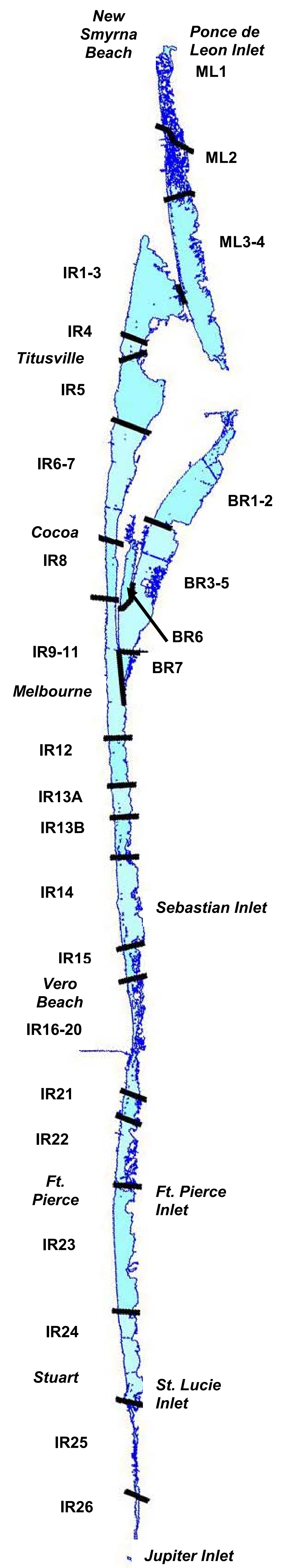
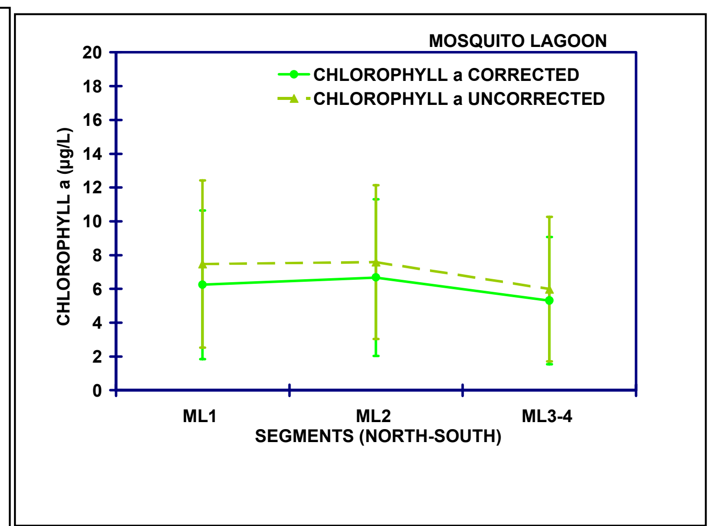
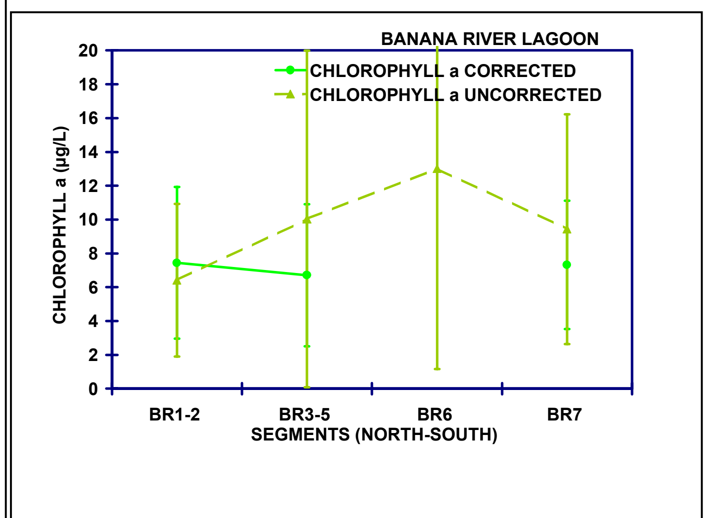
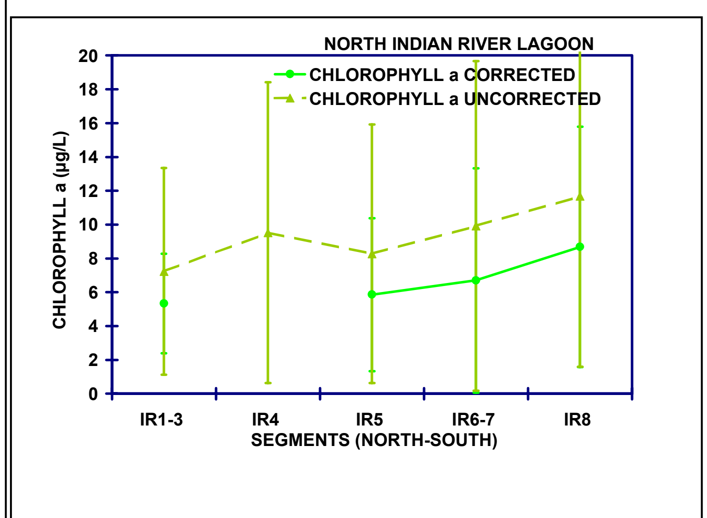
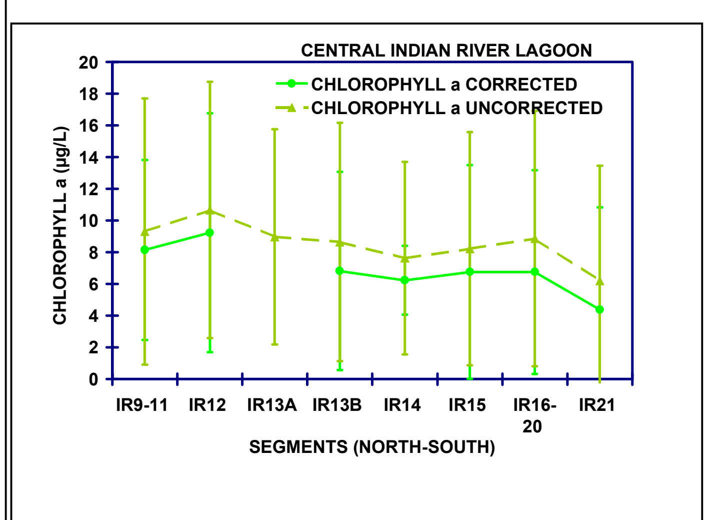


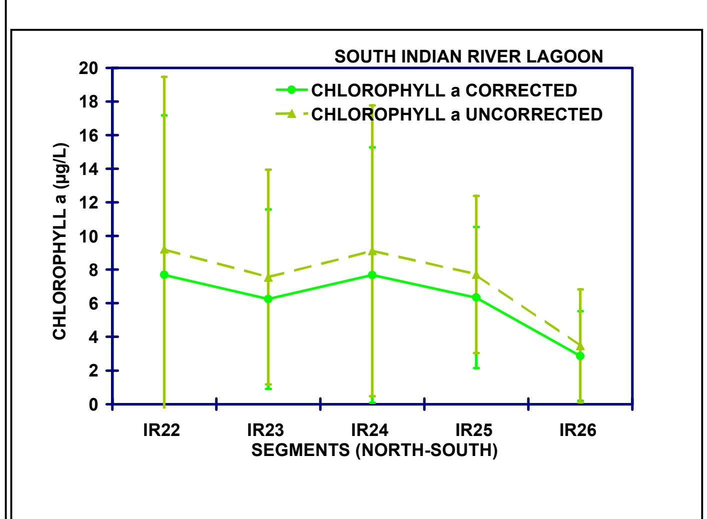
Figure 2-6. Spatial distribution of total nitrogen, total phosphorus, & chlorophyll *a* throughout the IRL System (expressed as a mean of the 1990-1999 data with standard deviation bar). Refer to center map for location of segments.











growth (not necessarily survivability) of most seagrass species may be hampered even if other environmental conditions are good.

Color inversely tracks salinity trends in the Banana River Lagoon, Central and South IRL, where tributaries or canals discharge relatively high colored waters and, concomitantly, salinities can be substantially reduced. For most of the IRL, the 10-year average for color ranged between 15 and 20 platinum-cobalt units (pcu). The highest 10-year average color, 28 to 31 pcu, was found in Newfound Harbor (BR6, Banana R. Lagoon) and in the Vero Beach vicinity (IR16–20). Woodward-Clyde (1994b) found that the average wet season color in the Vero Beach area was 2 to 3 times the dry season levels, <10 to 15 pcu. Some of the lowest color levels were found in the South IRL, with Hobe Sound near Jupiter Inlet standing out with the lowest 10-year average, <10 pcu.

Average turbidity levels in Banana River Lagoon, North and Central IRL generally do not exceed 6 nephelometric turbidity units (ntu), and are typically half that level. In contrast, Mosquito Lagoon and South IRL frequently average above 6 ntu. In the South IRL, the segment immediately south of Ft. Pierce Inlet (IR23) experienced both the highest 10-year average and the highest variability in turbidity levels: approximately 7 ± 7 ntu.

These turbidity trends may be explained by contributions from total suspended solids (TSS). This relationship may be a reasonable explanation since the spatial pattern for TSS roughly mirrors the pattern for turbidity, although disparities are apparent in some segments. Further analysis indicates that TSS concentrations do contribute significantly to turbidities in certain segments, especially in the Mosquito, Banana, and North Indian River Lagoons.

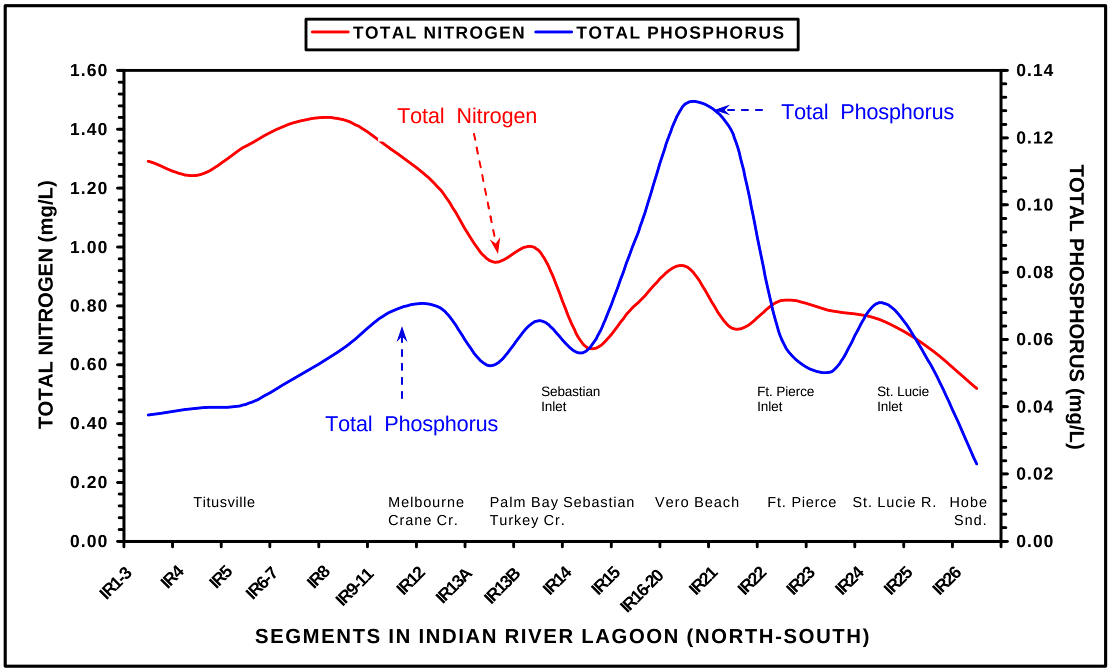
Average TSS levels throughout the IRL system range from 18 to 34 mg/l. It is interesting to note that the Cocoa-Melbourne segments of the IRL (IR9-12) exhibited the lowest average TSS level in the Lagoon system (10-year average is about 18 mg/l). Given the extent of development, the augmented drainage discharges, and relatively small open water area in that reach, one would expect average TSS levels that are higher, if not comparable, to the North IRL and Mosquito Lagoon with TSS levels typically >20 mg/l[5].

From North Banana and Indian River Lagoons through the South IRL, there is a general north-to-south decrease in total nitrogen (TN) concentrations (Figure 2-7). The 10-year average concentrations of TN range from >1.4 mg/l just south of Titusville to ~0.5 mg/l in Hobe Sound. Upward spikes of TN concentrations are also apparent in the Palm Bay and Vero Beach areas. The large concentrations of TN in the northern reaches of Banana and Indian River Lagoons (Figure 2-7) may reflect the large standing pool of organic nitrogen (up to 95% of TN is organic) and plant biomass that can take months to more than a year to flush (based on preliminary hydrodynamic model results, SJRWMD).

Total phosphorus (TP) concentrations exhibit more numerous spikes in areas adjacent to intensively developed sub-basins and large discharge tributaries and canals in the Central and South IRL (Figure 2-7).

[5] It is believed that the lower-than-expected TSS concentration results in the Cocoa-Melbourne area is an artificial anomaly created by sampling design. It may be due to sampling locations – several sites are in the “wind shadow” of causeways -- or due to sampling times, which are generally in the morning when the sea state is typically calmer than in the afternoon. Modifications to the sampling network will be evaluated to minimize this possible bias.

Figure 2-7. North-to-South Spatial Trend in Total Nitrogen & Phosphorus Concentrations in the IRL
(10-year averages: 1990 – 1999)



One such TP spike peaks dramatically in the Vero Beach segment (IR 16 –20), with 0.13 mg/l as the 10-year average. The Vero Beach segment receives discharges from three large canals: North, Main, and South Canals. These canal discharges, combined, constitute the largest TP loading in the IRL system (~35 metric tons of TP per year; SJRWMD data). Hobe Sound, again, is where the lowest TP concentrations are generally found; the10-year average was about 0.02 mg/l (Figure 2-7)

Phytoplankton response to these spikes in nutrient levels is apparent in the Cocoa/Melbourne area (segments IR8 through IR12), where chlorophyll *a* levels are above 8 µg/l (10-year average, Figure 2-6). However, such an algal response is not seen the Vero Beach area (segment 16 – 20), which may be due to the much shorter residence time or higher flushing rates (2 to 3 weeks) as compared to the Cocoa/Melbourne area (3 to 6 months; based on preliminary hydrodynamic model results, SJRWMD). The Vero Beach area also has higher average color (limiting light for phytoplankton growth) than the Cocoa/Melbourne area – 31 pcu and 21 pcu, respectively. A similar, albeit slight algal response is seen in the Ft. Pierce and St. Lucie River areas (IR 22 and 24 segments), where chlorophyll *a* levels approach 8 µg/l. Moreover, chlorophyll *a* levels in segments IR 8 – 12, IR 22, and IR24 can vary widely as compared to other segments, sometimes reaching ‘bloom’ levels of 30 to 50 µg/l.

In summary, the Lagoon areas with the worst water quality conditions are the Cocoa to Melbourne/Palm Bay (segments IR9-13A), Vero Beach (segment IR16 – 20), Ft. Pierce (segments IR21 & IR22), and St. Lucie reaches (segments IR24 & IR25). Most of these reaches are also listed as critical seagrass restoration areas (see Figure 2-4).

Relatively low salinities, and high color, nutrients, and chlorophyll *a* may be the compounding factors that are contributing to the poor conditions in the Cocoa/Palm Bay reach. The Vero Beach area may owe its poor condition to color, turbidity, and possibly nutrients. The South IRL segments near Ft. Pierce and St. Lucie appear to be aggravated by high turbidities, TSS, and nutrients, along with the associated algal response as indicated by spikes in chlorophyll *a* levels. Areas near the larger tributaries and canals – Crane Creek, Turkey Creek, Sebastian River, the North, Main, and South Canals in Vero Beach, and St. Lucie River – also experience higher than typical levels in TSS, color, and nutrients (TP being the most obvious).

Other areas of the Lagoon system, southern Mosquito Lagoon, northern Banana River Lagoon and North IRL, exhibit appreciable levels of turbidity, even though their seagrass coverages are fairly robust. Perhaps it is fortunate that the other, possible compounding factors (color, nutrients and chlorophyll) are present at fairly low levels; otherwise the good seagrass status of these areas could be jeopardized.

Preliminary Identification of Factors that Affect Light. Preliminary results, based on analyses[6] to date, indicate that turbidity, color, and chlorophyll *a* are the primary factors that affect the amount of light reaching the Lagoon bottom (Table 2-1). Analysis of Lagoon segments individually shows some differences, particularly in the order of dominance among the factors, but the results are basically consistent throughout the IRL system. A separate investigation by Harbor Branch Oceanographic Institution (Hanisak, 2001) confirmed turbidity and color as the dominant factors in the Banana River Lagoon and the Central IRL. In combination, these water quality factors may account for 30-50% of the attenuation of light through the water column.

Turbidity is a result of the combination of several constituents in the water column – organic suspended solids (living and detrital, both algal and non-algal) and inorganic or mineral suspended solids. In much of the Lagoon system, an overwhelming majority of the suspended solids is mineral in nature (=70%). Much of this mineral fraction can probably be traced to the runoff and re-suspension of sediment material that has upland soil characteristics, which is also a major fraction of “muck” sediment.

Table 2-1. Preliminary Identification of the Principal Water Quality Factors Affecting Light in the IRL System

Sub-Lagoon Area	Principal Factors (Preliminary)
Mosquito Lagoon	Turbidity
Banana R. Lagoon	Turbidity, Chlorophyll *a*
North, Central, South IRL	Turbidity, Color (particularly in S. IRL)
Lagoon-wide	Turbidity, Color, Chlorophyll *a*

Another factor that can restrict the availability of light to seagrass is epiphyte (attached algae) growth on seagrass blades. A study specifically investigating this possibility in

[6] Principal component analysis and step-wise regression analysis used to identify and quantify the degree of contribution from each water quality factor to its attenuation of light (SJRWMD analysis; Hanisak, 2001)

the IRL found that the abundances of epiphytes were not significantly different throughout the Lagoon system (Miller-Myers, 1997). Therefore, epiphytes are probably not contributing to the spatial heterogeneity in seagrass coverage; however, epiphytes are probably contributing to light limitation generally throughout the system. Other studies indicate that epiphytes may 'shade' as much as 50% of available light to seagrass blades (Harden, 1994; Dixon, 2000). Since these studies show that epiphytes are an important light limitation factor, possibly as important as phytoplankton chlorophyll *a*, then the reduction of nutrient loads, as well as suspended solids, should be seriously considered.

The next section, *Projects and Progress to Date*, develops the rationale for the major strategies to improve water quality (specific to the "optical pollutants") and seagrass coverage; and briefly describes the projects required to accomplish the strategies. The major strategies, or more accurately, the long-term campaigns, are (1) the management of surface water runoff and tributary discharges, and (2) the control of muck sources in concert with the removal of major muck deposits. Resources to wage these campaigns will be focused more in the Central and South IRL and the sub-basins therein.

Projects and Progress to Date

Lagoon-wide Monitoring and Diagnostics. Monitoring and diagnostic research are needed to evaluate the condition of the system and determine the (potential) causes of impact. This chapter's opening section, *The Lagoon-wide Status of Seagrass and Water Quality*, would not have been possible without long-term monitoring and diagnosis. Additionally, in order to manage seagrass areas, it is necessary to first map and quantify the spatial distribution and temporal status of seagrass coverage relative to established coverage target(s). Then, the areas of coverage loss or gain are diagnosed to determine the causes. It is assumed that successful diagnosis requires a better, quantitative understanding of the water quality/light relationship – as water quality changes so does the depth extent of light and the corresponding coverage of seagrass. Therefore, as a means to collect assessment and diagnostic data, seagrass, water quality, and hydrological monitoring programs were established within months following passage of the SWIM Act in 1987, and have continued since then. Descriptions of these Lagoon-wide monitoring projects are provided below.

At least two levels of seagrass monitoring are utilized: (1) Lagoon-wide mapping of seagrasses (based on aerial photography) and (2) site-specific monitoring of seagrass density, diversity, and other indicators of health (Virnstein and Morris, 1996).

Lagoon-wide maps of seagrass coverage, produced by SJRWMD and SFWMD, have been completed for the following years: 1986 and1989 (except Mosquito Lagoon), 1992, 1994, 1996, and 1999. Maps are generally developed every 2 to 3 years. In the intervening years, aerial photography of seagrass coverage is processed, archived, and can be used to detect any short-term changes. Areas of seagrass loss or gain are determined from previous years' coverages. For example, 1943 is considered the baseline year for most areas of the IRL from which loss/gain determinations can be made. Trends can also be determined by comparing any mapped coverage to the potential coverage, based on the 1.7 m target depth, which is the ultimate seagrass restoration target (Virnstein et al., 2000).

The site-specific monitoring of seagrass at 74+ locations throughout the IRL started in 1994. This large, semi-annual monitoring project is managed by SJRWMD with substantial fieldwork support by a number of agencies[7] and individuals. Information on seagrass coverage density, species distribution, and general health status is generated from this level of monitoring.

Water quality data relevant to the seagrass condition are collected through various monitoring projects supported or undertaken directly by the two Districts. In 1988/89, each District established a water quality monitoring network[8] in their respective segments of the IRL. The monitoring is designed to detect general spatial conditions and year-to-year trends in water quality at key locations in the IRL. These key locations are representative of water quality conditions throughout relatively large areas of the Lagoon, which can affect (both actual and potential) seagrass coverage. The Districts have continually improved their respective portions of the network over the years to generate better, more specific information, on the seagrass-water quality environment (Sigua et al., 1996).

Monitoring data are also being used to help diagnose changes in seagrass coverage. As stated above, this diagnosis is based on the premise that a certain level of sunlight is required by seagrass, which is restricted by interfering substances in the water (such as suspended solids, color or dissolved substances, algae concentrations). A concerted effort is underway, through this monitoring network and other data-intensive investigations and modeling, to determine which substances are the primary "optical pollutants."

Since 1993/94, several intensive, short-term investigations[9] have been conducted in an attempt to answer questions concerning light level requirements for seagrasses, and the effects of epiphyte[10] abundance and various water quality constituents on light levels. These studies indicate that the IRL is not homogeneous; there is spatial variability among IRL segments with respect to the water quality constituents that are suspected to affect light and seagrass distribution. Preliminary findings of these studies, complemented by data from the Lagoon-wide monitoring networks, are presented in the previous section, *Lagoon-wide Status of Seagrass and Water Quality.*

The Lagoon system's physical processes – meteorological, hydrological, hydrodynamic – do affect the system's water quality and seagrass status. Consequently, a network of instrumented sites collecting data on these physical processes was established and has expanded since 1988/89. The instrumented sites, distributed throughout the major sub-basins and sub-Lagoons, provide physical data on rainfall, wind, atmospheric deposition of nutrients, stream discharges, water elevations, estuary current velocities, salinity, temperature, etc. These data are just as crucial to the calibration of estuary models as the data on water quality and macrophyte productivity. Additionally, detailed bathymetric measurements of the Lagoons and major tributaries were completed in the last 5 years. These measurements are essential to a variety of efforts including the calibration of models, the setting of seagrass depth targets, and muck dredging projects.

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[7] Agencies that participate in the seagrass monitoring project are the Canaveral National Seashore, NASA-Dynamac, FDEP Aquatic Preserve offices, USFWS (Vero Beach office), SFWMD, and the Loxahatchee River District.

[8] In the SJRWMD segments of the IRL, Volusia and Indian River counties and NASA-Dynamac performs much of the fieldwork, which was coordinated and funded by SJRWMD. Brevard County was also a participant up until 2001. SFWMD performs the fieldwork in the south IRL.

[9] These investigations were conducted by Harbor Branch Oceanographic Institution, National Marine Fisheries Service, Florida Institute of Technology, and Smithsonian Institution; all funded by SJRWMD, SFWMD, Sea Grant, and NEP.

[10] Algae attached onto other plants, for example, onto seagrass blades.

Pollutant Load Reduction Goals & Related Modeling Efforts. The data and information generated from the studies and monitoring activities described above are also being applied toward the calibration and verification of numerical models, which are intended to assist the Districts in the development of pollutant load reduction goals (PLRGs). PLRGs are numerical targets for the reduction of pollutants believed to contribute to the loss of seagrass coverage in the IRL. These pollutants include the major nutrients, (nitrogen and phosphorus), suspended matter; and dissolved organic matter (typically measured as 'color'). PLRGs will be established for discrete segments of the IRL and their associated drainage sub-basins.

Additionally, reduction targets for freshwater discharges are being considered for specific drainage sub-basins: St. Lucie River, C-25, Sebastian River, Turkey Creek, and possibly Crane Creek and Indian River Farms Water Control District. In those sub-basins, extensive drainage systems have been constructed, designed to deliver tremendous volumes of drainage (particularly storm water) rapidly to the IRL. The IRL, being an estuary, can absorb occasional excessive discharges with minimal impact. However, over the last several decades, those drainage systems have increased the frequency of excessive discharges. It is believed that these recurring discharges have resulted in frequent, precipitous, and/or prolonged drops in salinity as well as increased loading of pollutants in affected IRL segments. Over the long term, these impacts have worked in concert to diminish seagrass resources, clam and oyster fisheries, and other valuable resources. (Further discussion about these impacts can be found in the 1994 IRL SWIM Plan; pp. 33 – 44, and p. 59).

To restore the impacted resources, it is important to establish and pursue targeted reductions in pollutants and excessive discharges. But, to what level do we set the reductions? And, which pollutants are significant and should be targeted? To help answer these and other management questions, each District is engaged in the development of models intended to predict and quantify specific responses of the IRL system (like salinity, other aspects of water quality, and potential seagrass coverage) to changes in pollutant loadings and discharge levels. The SJRWMD and SFWMD began work on their estuary models in the mid-1990s. Presently, efforts are directed at the calibration and verification of these models using Lagoon-specific data to improve accuracy in the models' predictive results.

The SJRWMD, through its University of Florida[11] contractor, has nearly completed the calibration of the Pollutant Load Reduction (PLR) Model. The PLR Model is a 3-D representation of the estuary from Ponce de Leon Inlet to St. Lucie Inlet, which incorporates a number of essential, interactive processes: hydrology, hydrodynamics, salinity, water quality, and light (Steward et al., 1996). The SFWMD and U.S. Army Corps of Engineers are also developing a multi-dimensional model for the South IRL with special emphasis on the St. Lucie River estuary.

Additionally, both Districts employ sub-basin hydrologic models as a means to generate watershed data for input to the estuarine models and to serve as analytical tools in the evaluation of proposed PLRGs and sub-basin management strategies (e.g., surface water reservoirs or treatment areas). The sub-basin models are being applied where necessary and in prioritized fashion. This prioritization, as presented below (Table 2-2), also serves as the general schedule for the development of final PLRGs.

[11] Dr. Y. P. Sheng , Principal Investigator; Sub-Principal Investigators: Drs. Reddy, Phlips, and Montague.

Table 2-2. Prioritization of sub-basins in the IRL System (1994 – 2007)

SJRWMD sub-basins – PLRGs recommended by end of 2004

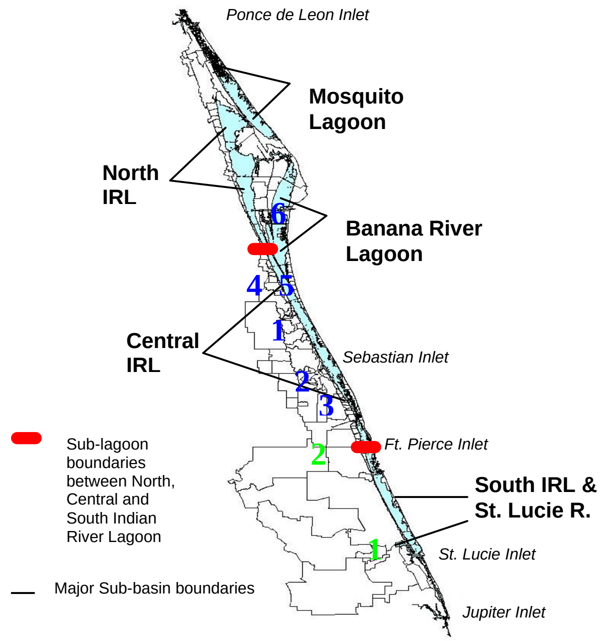
1. Turkey Creek/C-1 canal
2. Sebastian River (includes Sebastian & Fellsmere WCDs)
3. Indian R. Farms WCD/Vero Beach
4. Crane Creek
5. Eau Gallie River
6. S. Merritt Island

Other sub-basins as needed

SFWMD sub-basins – PLRGs recommended by end of 2006

1. St. Lucie River (includes C-23, C-24, C-44)
2. Ft.Pierce/C-25 (includes Virginia Ave.)

Other sub-basins as needed



Until final PLRGs are established, provisional PLRGs for the SJRWMD portion of the IRL system are provided to address the immediate need for reduction target/design criteria for regional or watershed projects that are currently being planned. Provisional PLRGs are fairly conservative approximations of desired pollutant reductions, and for some sub-basins, may be more stringent than final PLRGs. Provisional PLRGs are calculated via inference; utilizing data on rainfall, land use, and soil hydrology of c.1943 – the best-documented year for maximum seagrass coverage (Virnstein and Morris, 2000) -- to numerically *infer* runoff pollutant loading rates. The result is considered an "allowable" loading rate, which is subtracted from current loading or build-out loading (preferable) to obtain a load reduction target (Steward, 2002). Provisional PLRGs for major segments or sub-basins in the SJRWMD portion of the IRL system are listed in Chapters 3, 4, and 5[12].

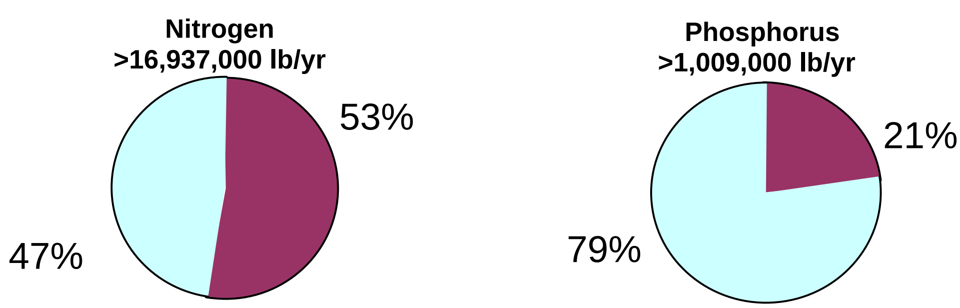
General Management Strategies for Pollutant Load Reduction. Monitoring and diagnosis are critical steps that will continue to improve our understanding of cause-effect phenomena and the magnitude of impacts related to discharges and pollutant loadings. These same steps are also critical to the development of efficient, cost-effective management strategies for achieving PLRGs. Since 1994, both Districts have increasingly emphasized the reduction of major, non-point sources of pollution. Although non-point source control is the key toward truly significant reductions in pollutant loads, reductions in point source loadings are also important. The general, Lagoon-wide approach to the management of non-point and point sources is briefly discussed below. Strategies specific to sub-lagoons and their associated sub-basins are discussed in the chapters that follow.

[12] Tables 3-2, 4-3, 5-4 and 5-5, respectively; and discussed as part of the planning for Central IRL sub-basins on pp. 5-20 through 5-28).

General Non-Point Source Strategies. The SWIM strategy is to concentrate efforts and financial resources on controlling the *major* non-point sources of pollution. Early in the SWIM program, quantification of inputs from various sources was a primary effort; and this effort continues to further improve accuracy and confidence in the results. Preliminary estimates indicate that the sedimentary diffusive loading and external loading[13] of nitrogen (N) may be nearly equal (Figure 2-8). For phosphorus (P), the external watershed loading is much greater than that from sediment diffusion (Figure 2-8). The partitioning of N and P loading between internal and external sources may change as additional data are generated. For example, the nutrient loading via advective flux[14] from the sediments is currently unknown, but could be a significant internal loading source.

At this time, these estimates confirm that surface water drainage is, by far, the major external source of N and P. Muck sediment is the major internal source of N and P in the IRL, based solely on the diffusive process. Additionally, surface water drainage accounts for nearly all (~99%) of the annual suspended solids loading of 121,292,000 lb/yr to the IRL. Therefore, significant reduction in non-point source loadings can be achieved by pursuing two basic strategies: (1) treatment and/or volume reduction of surface water discharges to the extent feasible, and (2) muck removal where it is most effective and practical to do so.

Figure 2-8. Preliminary Nutrient Loading Estimates
Sediment Diffusion vs. External Sources



Sediment Sources **(based on diffusion only)**
79% of N and 65% of diffusive P loading is from mucky as opposed to sandy sediments; and most of the mucky sediment is in the Central IRL.

External Sources **(runoff, stream, WWTP, atmospheric, and groundwater)**
70% of N and 90% of external P loading is from surface runoff and stream/canal discharge; and most of those sources are in the Central and South IRL.

While these strategies are generally applicable Lagoon-wide, more attention is being paid to the Central IRL, South IRL (including St. Lucie River sub-basins), and the southern

[13] External loading estimates are derived from SJRWMD (1986 – 1999) and Woodward-Clyde (1994) sub-basin discharge and loading estimates, FDEP personal communications and file records on WWTPs, and precipitation loading estimates from National Acid Deposition Program, EPA (1997 and 1998)

[14] Advective flux is the movement of material solely by the mass movement of water as opposed to diffusive flux (or loading), which is the movement of material driven primarily by differences in concentration. To date, the diffusive flux of nutrients in the IRL is generally quantified, but not the advective flux.

Banana River Lagoon. These regions constitute the vast majority of surface water drainages – several large sub-basins extensively drained by a network of inter- and intra-basin canals[15]. Stemming the rate of stormwater discharges and implementing base flow treatment measures are key components in these sub-basin plans. The plans for the few major sub-basins that receive interbasin drainage diversions must also address freshwater/ salinity impacts by setting and implementing salinity-based discharge criteria, not only to protect seagrasses, but for the hard clam resource in the Central IRL (specifically related to Turkey Creek, and Sebastian River) and for oysters in the St. Lucie River estuary[16].

As part of plan development, sub-basin or watershed modeling is essential; not only to evaluate measures intended to meet environmental criteria, but also to ensure that flood protection, water supply, and other water resources are not jeopardized. Planning activities and modeling work are focused on high priority sub-basins (as listed in the 1994 IRL SWIM Plan and above in Table 2-2) and involve many local jurisdictions[17]. In fact, most activities could not be done without approval or cooperation by the local jurisdictions. Implementation of sub-basin plans is underway in the priority sub-basins: St. Lucie River, C-25, Turkey Creek, and Sebastian River. These sub-basin activities are discussed in more detail in the following chapters.

Of course, successful implementation of the sub-basin plans would mean PLRGs should be met for nutrients, suspended solids and/or other pollutant loads. Controls on upland sources of nutrients and suspended solids, in particular, should also mean a decrease in the rate of muck sediment deposition in the IRL. Once upland source controls are in place, the removal of major muck deposits can proceed as a means of diminishing another large source of nutrients and suspended material. Projects addressing muck removal and source control are underway in the priority sub-basins and associated Lagoon segments with major support from several local governments, the Florida Inland Navigation District (FIND), and U.S. Army Corps of Engineers (USACE). For example, the SJRWMD, FIND, and partner cities[18] have or are in the process of removing huge volumes of muck from major Lagoon tributaries (details of these projects are provided in the chapters on North and Central IRL, South IRL, and St. Lucie River). The USACE is now planning the 'environmental' muck dredging of the Intracoastal Waterway over the next 10 years, commencing with the North and Central IRL segments in Brevard County.

General Point Source Strategy[19]. Prior to 1995, 15 to 20% of the annual external loading of nitrogen and phosphorus to the IRL was contributed by domestic wastewater treatment plants (WWTPs). Compared to non-point source loadings Lagoon-wide, this point source contribution seemed relatively minor. Nevertheless, point source loadings still represented a fairly large input, especially when one reviews individual segments where

[15] Descriptions of the sub-basin drainage systems – inter-basin and intra-basin – can be found in the IRL Reconnaissance Report (SJRWMD and SFWMD, 1987), 1994 IRL SWIM Plan, Woodward-Clyde Report to IRLNEP (1994), and the IRLNEP Comprehensive Conservation & Management Plan (1996).

[16] Refer to chapter 5: Sub-basin Water Management Plans; and to Chapter 7: Oysters, SAV, and Water Quality for further information on utilizing shellfish resources as a basis for setting salinity targets.

[17] Primarily cities, water control districts, and counties affected by surface water management plans.

[18] New Smyrna Beach – Canal St. Cove; City of Melbourne – Crane Cr.; City of Palm Bay – Turkey Cr.

[19] This SWIM strategy primarily addresses domestic WWTPs. FDEP is the agency responsible for permitting and monitoring all point source facilities, both domestic and industrial. An FDEP list of permitted industrial facility dischargers is found in Appendix B.2. FDEP finds that permitted industrial facilities present no apparent threat to the IRL (M. Paulic, personal communication, 10/17/02, based on statement from FDEP Central District office).